Evaluation of ERTS-1 imagery for mapping Quaternary deposits and landforms in the Great Plains and Midwest

(SR 238)

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16. Abstracts

Maps at 1:1 million scale exemplifying the first phase of investigation (which consists of identifying and mapping landform and land-use characteristics and surficial geologic materials directly from the ERTS-1 images without use of additional data) were prepared during this reporting period for ten study areas (mostly 1° x 2° in area): 2 in Kansas, 1 in Missouri-Kansas, 2 in Nebraska, 1 in South Dakota, 3 in Illinois, and 1 in Iowa-Illinois (a total of 13 such maps, covering about 97,000 sq. mi., since the start of the project). Collection of all pertinent published (and some unpublished) geologic-terrain data also has been completed for all the study areas for which these first-phase maps have been made. The "ground truth" data are being used in combination with additional interpretation of the repetitive ERTS-1 images (including analysis of phenologic changes) of most of these study areas to prepare "enhanced information maps" at 1:500,000 scale.

For areas that have not been mapped at 1:500,000 or larger scales, our maps will provide the first moderately detailed information on landform features and surficial materials. Much of the information mapped is significant for exploration and development of ground water (and locally petroleum) and for applications in engineering and environmental geology, and land-use patterns as indicated by tone and texture on the images. Numerous moraines of the last glaciation have been identified, as well as several trend-lines that suggest former moraines of older glaciations; also, the trends of parts of various ancient filled valleys have been identified by analysis of stream-valley widths. Alinement of certain valleys appears to be controlled by faults or other structural "lineaments".

17. Key Words and Document Analysis. (a). Descriptors

Quaternary geology and geomorphology; landform analysis and surficial-deposits mapping; regional land-use planning; soil survey; moraines; ancient river valleys and river terraces.

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Type II Progress Report

ERTS-1

A. Evaluation of ERTS-1 imagery for mapping Quaternary deposits and landforms in the Great Plains and Midwest. ERTS-A Proposal No. SR 238.

B. GSFC ID No. of Principal Investigator: IN 404

C. Problems encountered:

Poor atmospheric conditions--haze, smog, and clouds continue to degrade many of the ERTS-1 images of the Great Plains and Midwest, particularly in Illinois, Iowa, and Missouri. We still lack imagery of satisfactory quality for large parts of the Rockford and Aurora (Illinois), the Dubuque (Illinois-Iowa), and the Waterloo and Fairmont (Iowa) study areas and have decided to eliminate them from the program.

D. Accomplishments during the reporting period:

All ERTS-1 images received for the six-state region of this project during the reporting period continued to be indexed and evaluated in terms of coverage of the 24 potential study areas, cloud cover, contrast, resolution, atmospheric degradation, other defects, and also the geologic-terrain features displayed. Copies of the evaluation sheets were sent to each State Geologist, describing and evaluating the ERTS-1 images we have received for his State.

The color-infrared (2443 film) 9 1/2 x 9 1/2-inch and multispectral 70 mm airphotos resulting from two ferry flights over the project region by NASA's U-2 aircraft, on March 21 and 30 (Flight Nos. 73-040 and 73-048), were indexed and evaluated. Single flight lines were made that cover parts of Illinois, Iowa, Missouri, Kansas, and South Dakota. The time-of-year that this photography was taken is about optimum for the purposes of this project, because vegetative cover still was minimal in the croplands, pasture and rangelands, and woodlands. Relatively few frames are seriously obscured by clouds. The 9 1/2 x 9 1/2-inch 2443 color-infrared airphotos are proving to be most useful: resolution and contrast are very good and this film "penetrates" haze and smog very well. We have sent copies of these transparencies to the respective State Geological Surveys and have received several enthusiastic thank-yous. We tried additive color viewing of some of the Vinton multispectral 70-mm airphotos using an I²S Minniaddcol. The results were much poorer than those obtained with the 9 1/2 x 9 1/2-inch color-infrared transparencies, because of lower resolution.

Phases 1 through 5 of our six-phase program of analysis (see Appendix) were in progress for various study areas.

Phase-1 results

Phase-1 analysis consists of interpreting landform and land-use characteristics and surficial geologic materials from the ERTS-1 images alone, without using additional data. All of the phase-1 maps are prepared at 1:1 million scale as overlays to enlargements of the ERTS-1 images to this scale. Examples of phase-1

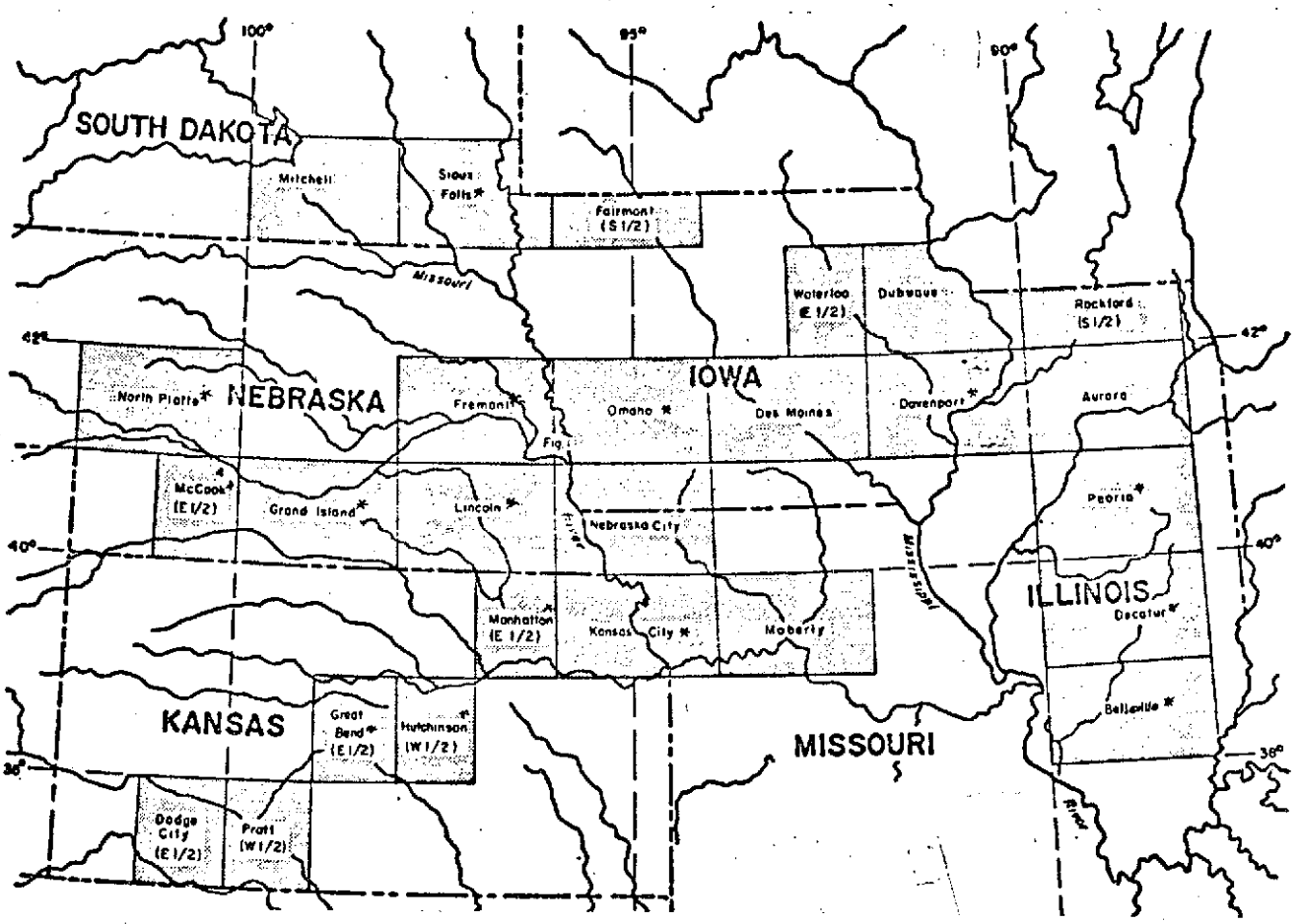

Figure 1. Potential study areas for project SR 238. Asterisk after the 1 x 2 quadrangle name indicates that the study has progressed at least through phase 2.

maps of various study areas have been given in the 1 January 1973 Type II Progress Report and in the 1 March and 1 May 1973 Type I Progress Reports.

For identification and mapping of landforms, topographic information obviously is needed. In airphoto interpretation, this information is obtained most fully by stereoscopic viewing. Unfortunately, the ERTS images provide rather limited capability for such viewing, particularly in the Great Plains-Midwest. True stereovision is not provided by the 10% end-lap of consecutive frames along a track (the same scan lines appear in the overlapping areas of both frames). Stereovision is possible where frames from adjacent orbital tracks side-lap with each other; commonly 40 to 60% of a frame has such side-lap coverage. However, the limited parallax resulting from the high orbital altitude, together with the low relief in most of the Great Plains-Midwest, severely restricts the usefulness of stereoscopic viewing of ERTS images for geologic-terrain interpretation in this region. Consequently, landforms must be interpreted largely from land uses.

Land uses can be deduced from tonal (gray-level or density), pattern, and "textural" variations in the images. Landforms and landform associations are interpreted primarily from agricultural patterns, including not only field patterns, but also the patterns of pasturelands, woodlands, and rural roads. The size of fields and the regularity of their shapes (square or rectangular vs. irregular) are controlled by the topography. Concentrations of very large (greater than 160 acres) fields with regular shapes and sharp boundaries generally indicate areas of very low relief and low drainage density, such as broad flood plains and flat or gently undulating uplands. The distribution of woodlands provides much information on the character of valleys and escarpments. In the areas of good soils, woodlands are restricted to slopes too steep to be farmed, i. e., the steeper valley sides. In the more arid parts of the region the steeper slopes commonly are partly woodland or brushland and partly pastureland.

Landform characteristics also can be interpreted indirectly from analysis of stream density, stream dissection and drainage patterns, and stream-divide relations--again mainly as revealed by land-use patterns, supplemented where possible by stereoviewing. It is important to make these higher levels of landform interpretation because only through them is it possible to detect anomalies that may point to the more ancient and obscure features that we are looking for, such as "palimpsests" of ancient moraines and buried river valleys. Detecting landform anomalies from ERTS images of the Great Plains-Midwest is more difficult than in regions of higher relief, less vegetative cover, and less atmospheric haze.

Interpretation of the surficial geologic materials involves secondary and tertiary levels of inference; hence, specific interpretations cannot be made at the phase-1 level, but must await the higher phases of analysis, including various kinds of "ground-truth" control. Nevertheless, some general inferences obviously can be made at the phase-1 level, for example, where the landform morphology indicates the underlying materials, as with alluvial lowlands and sand dunes.

The 1 March 1973 Type I Progress Report discussed the phase-1 interpretations and gave 1:1 million-scale maps of the Grand Island and Fremont, Nebraska, and the Davenport, Iowa-Illinois, 1° x 2° quadrangles. The 1 May 1973 Type I Progress Report gives similar phase-1 data for the Peoria and Decatur, Illinois

1° x 2° quadrangles. These maps show that commonly the boundaries of geologic-terrain units can be delineated more accurately on ERTS-1 images than on topographic maps of 1:250,000 scale. From analysis of drainage patterns, stream-divide relations, and land-use patterns as indicated by tone and textural variations on the ERTS-1 images, the trends of numerous moraines of the last (Wisconsin) glaciation were mapped, as well as several trend-lines that suggest control by former moraines of older glaciations, of middle and early Pleistocene age; also, the trends of parts of various buried (filled) valleys were identified by analysis of stream-valley widths. In the Fremont quadrangle, the infrared bands of images taken in October immediately after moderate rains show enhancement of soil differences, facilitating the mapping of gross soil associations and related surficial deposits.

Subsequent to April 30, we completed phase-1 studies of the following study areas (which are discussed below): the Kansas City, Kansas-Missouri, 1° x 2° quadrangle; the adjoining east half of the Manhattan, Kansas 1° x 2° quadrangle; the west half of the Hutchinson and the east half of the contiguous Great Bend, Kansas, 1° x 2° quadrangles (which together constitute a 1° x 2° study area); and the Sioux Falls, Iowa-South Dakota, 1° x 2° quadrangle. (We also completed the Belleville, Illinois, 1° x 2° quadrangle and the southwestern part of the Decatur, Illinois, 1° x 2° quadrangle (this study areas was discussed in the 1 May Type I report but prior to May satisfactory ERTS-1 coverage was not available for the southwestern part). Phase-1 mapping during this reporting period totalled about 71,000 square miles.

Manhattan-Kansas City, Kansas-Missouri, study areas:--These two adjoining study areas are mapped together on a single map and will be here referred to as a single study area. This area is deeply dissected by the Missouri and Kansas Rivers and their tributaries. All of it except possibly the extreme southwest corner was covered by continental glaciers one or more times during the middle and early Pleistocene, long prior to the last (Wisconsin) glaciation. Bedrock units are chiefly weak shales and sandstones with few resistant "ledge-formers." As a consequence of the generally non-resistant bedrock, the antiquity of the glaciation, and the deep dissection (which is mostly subsequent to the glaciation of this area), a mature topography has developed, with fairly broad valleys and rounded ridges in most places. Thick deposits of glacial drift and loess are restricted to the less-eroded uplands well back from the principal streams, in the northern and eastern parts of the study area. Only scattered, thin deposits of drift and/or loess occur elsewhere. Thus, a much smaller proportion of this area is underlain by such surficial deposits than in the study areas farther north.

The phase-1 map of this area attempts not only to distinguish the various landform units but also to differentiate the areas underlain by drift and loess from areas where bedrock is at or within a few feet of the surface. In this study area, the deep, mature dissection of the weak bedrock since the ancient glaciation has resulted not only in widespread erosion of the drift and other old Pleistocene deposits, but also in the formation of extensive younger colluvial mantle (over bedrock) on the valley slopes. Consequently, on the ERTS-1 images[1] it is difficult to distinguish accurately the boundaries between

[1] ERTS-1 images used (bands 5 and 7 unless otherwise specified): 1021-16333 (13 Aug), 1022-16385 (14 Aug), 1056-16273 (17 Sep), 1057-16332 (18 Sep), 1057-16334 (18 Sep), 1058-16390 (19 Sep), 1058-16392 (19 Sep), 1056-16273 (17 Sep), 1057-16334 (18 Sep), 1076-16391 (7 Oct), 1076-16393 (7 Oct), 1076-16384 (7 Oct) 1128-16282 (28 Nov) (band 7 only), 1128-16284 (28 Nov) (band 7 only), 1237-16345 (17 Mar), 1256-16401 (5 Apr), 1256-16403 (5 Apr), 1273-16345 (22 Apr), 1274-16400 (23 Apr), 1274-16403 (23 Apr).

areas where bedrock is at or close to the surface and areas of relatively thick drift and/or loess. Land-use patterns are less helpful for making this distinction than in most of the other study areas.

A parallelogram pattern of many reaches of the major streams (preferred orientations being northeast, northwest, and north) suggests that their alinement may have been controlled in places by several sets of faults and/or major joint systems. Several anomalous widenings of stream valleys may indicate crossings of ancient filled valleys whose trends differ from those of the present valleys. Analysis of drainage and divide patterns also suggests relicts of four divides that may have been controlled by former moraines of middle or early Pleistocene age. Two of the divides trend about 50 miles southeastward from the adjoining Lincoln (Nebraska) 1° x 2° study area and the other two extend about 30 miles southward from the eastern part of the Nebraska City (Neb.-Mo.-Kan.) study area.

Great Bend-Hutchinson, Kansas, study area:--This study area is in the unglaciated central Great Plains. Phase-1 interpretation of ERTS-1 images[2] shows that the principal streams, the Arkansas and Smoky Hill Rivers, have formed broad lowlands. The uplands are slightly to moderately dissected and have varying kinds and thicknesses of Pleistocene deposits over bedrock. Areas of probable eolian sand, of relatively thick loessic mantle, of bedrock with thin or no loessic veneer, and of alluvial deposits have been distinguished. In addition, a major valley widening has been identified that suggests a crossing of a large ancient filled stream valley. Also evident is a large alluvium-filled closed depression northeast of Great Bend, that probably resulted from subsidence. The stream pattern suggests alinement locally along faults and/or other structural lineaments; these structural features may be significant for exploration and development of both ground water and petroleum resources.

Sioux Falls, South Dakota-Iowa, study area:--This study area is much less complicated and easier to interpret from ERTS-1 images[3] than most of the others, because its western two-thirds was strongly glaciated during the last (Wisconsin) glaciation, resulting in young drift plains of low relief. Two conspicuous divisions of these plains are evident, one characterized by many lakes and ponds (best displayed on the infrared bands) and another that has few ponds and lakes; these divisions probably discriminate areas of stagnation moraine

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[2] ERTS-1 images used (bands 5 and 7): 1058-16392 (19 Sep), 1058-16395 (19 Sep), 1076-16393 (7 Oct), 1094-16395 (25 Oct), 1095-16454 (26 Oct), 1130-16404 (30 Nov), 1256-16403 (5 Apr), 1256-16410 (5 Apr), 1257-16462 (6 Apr), 1257-16464 (6 Apr), 1274-16403 (23 Apr), 1274-16405 (23 Apr).

[3] ERTS-1 images used (bands 5 and 7): 1060-16491 (21 Sep), 1060-16494 (21 Sep), 1076-16382 (7 Oct), 1095-16442 (26 Oct), 1114-16500 (14 Nov), 114-16502 (14 Nov).

from areas of more typical morainal topography. The eastern part of the area is more dissected and has well-integrated drainage; it probably is an older drift plain.

Phase-2 results

Collection of all pertinent published (and some unpublished) data has been completed for all of the study areas for which phase-1 results have been reported. These "ground truth" data are chiefly geologic and some soil-survey reports and maps.

Phase-3, 4 and 5 results

The phase-2 data have been used in combination with phase-4 (additional interpretation of the repetitive ERTS-1 images to analyze phenologic changes) and phase-5 data (from field studies) of several of these study areas to prepare phase-3 "enhanced information maps" at 1:500,000 scale. Conferences regarding the interpretation of the ERTS-1 images were held with members of the State Geological Surveys of Missouri, Nebraska, and Iowa. Parts of the Moberly (Mo.), Kansas City (Mo.-Kans.), Manhattan (Kans.), Nebraska City (Mo.-Kans.-Neb.), Lincoln (Neb.), Fremont and Omaha (Neb.-Ia.), Des Moines (Ia.), and Davenport (Ia.-Ill.) study areas were visited in the field.

Plans for next reporting period

1) Complete the phase-1 and phase-2 studies of the Moberly (Mo.), Nebraska City (Mo.-Kans.-Ia.), Belleville (Ill.), Mitchell (S. D.), and Omaha (Neb.-Ia.) 1° x 2° quadrangles.

2) Complete the phase-3 through phase-6 studies in the above and all previously reported study areas.

3) Prepare the draft of the Type III (final) report on the project.

E. Significant results and their practical applications:

Maps at 1:1 million scale exemplifying the first phase of investigation (which consists of identifying and mapping landform and land-use characteristics and surficial geologic materials directly from the ERTS-1 images without use of additional data) were prepared during this reporting period for ten study areas (mostly 1° x 2° in area): 2 in Kansas, 1 in Missouri-Kansas, 2 in Nebraska, 1 in South Dakota, 3 in Illinois, and 1 in Iowa-Illinois (a total of 13 such maps, covering about 97,000 square miles, since the start of the project). Collection of all pertinent published (and some unpublished) geologic-terrain data has been completed for all the study areas for which these first-phase maps have been made. The "ground truth" data are being used in combination with additional interpretation of the repetitive ERTS-1 images (including analysis of phenologic changes) of most of these study areas to prepare "enhanced information maps" at 1:500,000 scale.

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F. Published articles, etc. released during the reporting period:

Hallberg, George R., 1973, ERTS-1 satellite study of Quaternary landforms and materials in the Midwest and Great Plains: a progress report (abs.): Geological Soc. America, Abstracts with Programs, v. 5, no. 4, p. 320.

Morrison, Roger B., 1973, Mapping Quaternary landforms and deposits in the Midwest and Great Plains by means of ERTS-1 multispectral imagery (abs.): Abstracts, NASA Symposium on significant results obtained from ERTS-1, March 5-9, 1973, Goddard Space Flight Center, Greenbelt, Md., p. 39.

G. Recommendations: None.

H. Changes in standing order forms: None.

I. ERTS image descriptor forms: See Type I Progress Report of 1 March 1973.

J. Data request forms submitted. April 30, 1973

K. N/A

APPENDIX

This project is using a six-phase program of interpretation and analysis of the ERTS-1 images:

Phase 1 consists of preliminary mapping of the pertinent geologic and geomorphic features using only the ERTS-1 imagery.

Phase 2 involves compilation of available published and unpublished ground truth data (geologic, soil, topographic, etc.), preferably on a map of the same scale as that prepared for phase 1, without using ERTS data.

Phase 3 is a comparison of phase 1 and 2 products, with additional photointerpretation, to prepare an "enhanced information" map (at scales ranging from 1:1 million to 1:250,000, as appropriate), noting any differences and anomalies.

Phase 4 consists of additional analysis made from ERTS repetitive coverage of the area, noting added information (at least the differences in information content) gained from time-variant phenomena such as changes in vegetation, soil moisture, snow cover, and plowing of croplands.

Phase 5 consists of appropriate field studies to obtain necessary additional ground-truth data, particularly to evaluate anomalies and interesting new features found in phases 3 and 4.

Phase 6 is the delineation of the new information detected from the ERTS imagery.